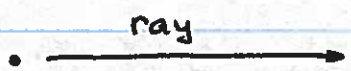
Ray optics

Statement: light ray in vacuum (air is too ok) travels in a straight line



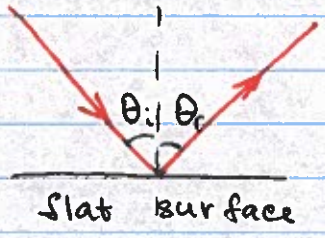
Best approximation of such a ray is a laser beam
It has <u>direction</u> and <u>brightness</u>

What happens if a ray hits an object?
- absorbed
- transmitted
- reflected / scattered

] often all three things happen in different propotions

We often talk about <u>reflection</u> when the ray bounces off in a predictable direction (mirror, flat surfaces)
When the direction is random / stochastic / changes dramatically depending of a spot — <u>scattering</u>

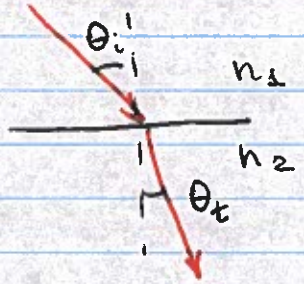
The law of specular reflection (speculum = mirror)



Angle of incidence = angle of reflection

$$\theta_i = \theta_r$$

Transmitted light experiences refraction - the change in propagation direction
We can characterise each material by how much speed of light is changed inside



$$v_{material} = \frac{c}{n}$$ (c in vacuum)

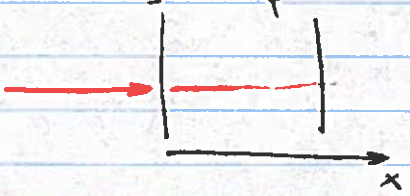
n - refractive index

Snell's law $\underbrace{n_1 \sin\theta_i}_{\text{one side}} = \underbrace{n_2 \sin\theta_t}_{\text{the other side}}$

Reflection and refraction describe change in the direction

Absorption describes dimming of the ray

Absorption coefficient α characterise optical losses per unit length of the material



$P(0)$ – input power (brightness)

$P(x)$ – light power after travelling distance x

$P(x) = e^{-\alpha x} \cdot P(0)$

The values of n and α are determined by how exactly the light interacts with his material, and are usually different depending on light wavelength / color.

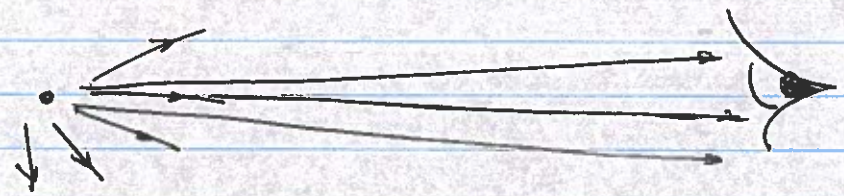
Let is talk imagine

What is object? Something you want to see

Think luminous object, consisting of many bright point sources → can image each point. " independently ".

Point source → emit rays in all directions

So for our purposes the "object" is going to be a point source at a specific location.

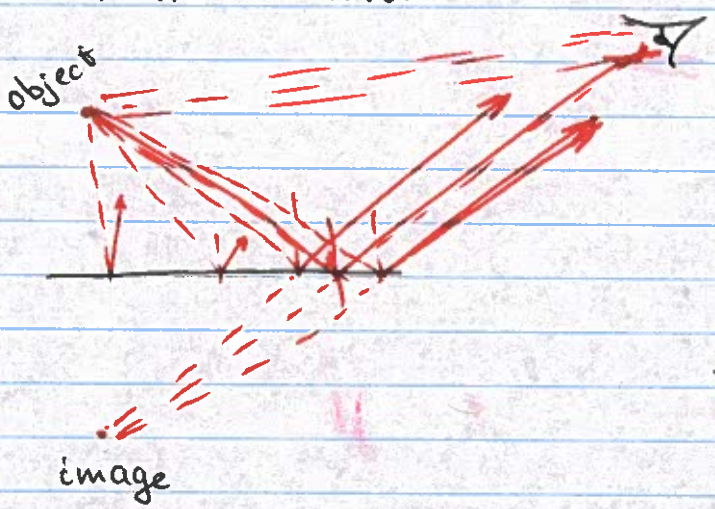


eye, camera

Very important: your eye (or a camera) is a complicated imaging system. When you see a point source at specific location, you eye collects multiple rays from the object, rearrange them, and then your brain interpret them to get the position information

Then what is image? A "fake" object When some optical elements (mirrors, lenses) change the direction of light coming out of our object point source, our eye+brain will interpret them as coming from a new location → image

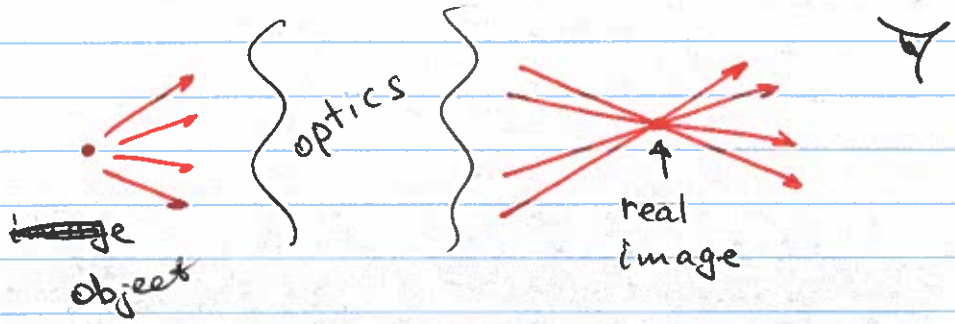
Flat mirror

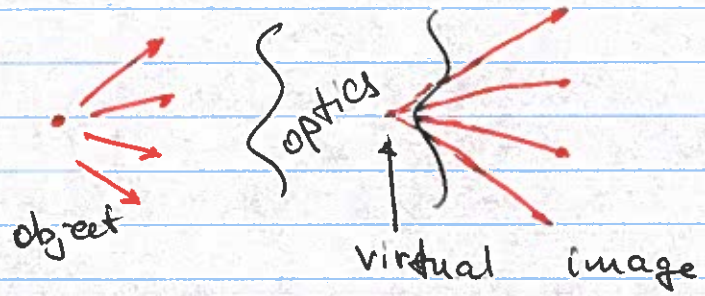


The reflected beams after the mirror travel as if they originate from a point behind the mirror → this point is the location of the image

This is a virtual image since the altered beams never cross
(Mental test → there is no point in space you can stick a screen and see a bright spot)

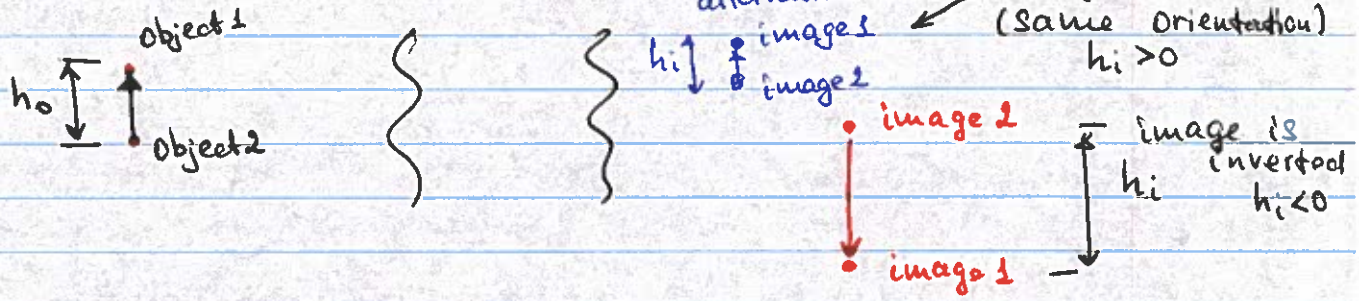
Lenses can creat real objects – a point in space where all altered beam cross again)





Other image properties : magnification

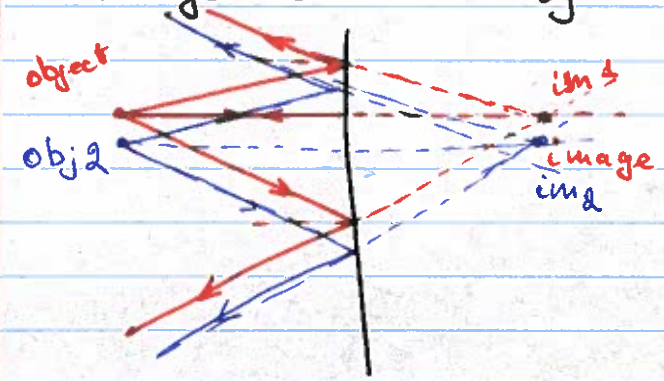
To discuss this we need at least two point sources to form our image



magnification $m = \frac{h_i}{h_o}$

$m > 0$ erect image $m < 0$ inverted image

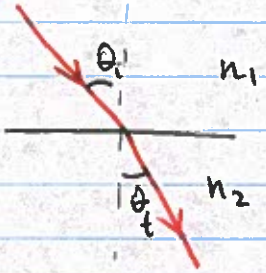
Image formed by a flat mirror



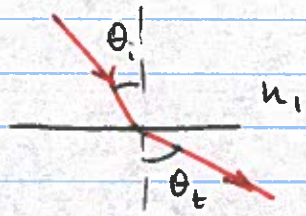
virtual
erect
$m = 1$

medium	n
air	1.00027
water	1.33
glass	~1.5
diamond	2.4

Seeing through transparent materials



or



$n_1 > n_2$

$n_1 < n_2$ $\quad \sin\theta_t = \frac{n_1}{n_2}\sin\theta_i$ $\quad n_1 > n_2$

$\theta_t < \theta_i$

A ray 'bends' closer to normal when crossing to denser material

$\theta_t > \theta_i$

A ray bends away from the normal crossing to the material with smaller refractive index